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**SCHOOL OF AVIATION MEDICINE
U.S. NAVAL AIR STATION
PENSACOLA FLORIDA**



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**A STUDY OF THE PHYSIOLOGICAL CHANGES
WHICH OCCUR DURING ACCLIMATIZATION
TO HIGH ALTITUDE**

**OCCURRENCE OF AERO-EMBOLISM AT
MODERATE ALTITUDES**

Research Project X-720(Av-376-s) Report No. 2

Submitted 4 September 1946

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NAVAL SCHOOL OF AVIATION MEDICINE
U.S. NAVAL AIR TRAINING BASES
PENSACOLA, FLORIDA

Research Report

Submitted 4 September 1946

PROJECT NO. X-720 (Av-376-s)

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WHICH OCCUR DURING ACCLIMATIZATION
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SUBTITLE: OCCURRENCE OF AERO-EMBOLISM AT MODER-
ATE ALTITUDES

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Opinions or conclusions contained in this report are those of the author. They are not to be construed as necessarily reflecting the views or endorsement of the Navy Department. Reference may be made to this report in the same way as to published articles noting author, title, source, date, project number and report number.

SUMMARY AND CONCLUSIONS

In the course of a thirty day study of acclimatization to increasing altitude in a low pressure chamber, twenty individuals made three hundred and eighty-seven lock ascents to altitudes ranging from 2,000 to 22,500 feet. Six of these individuals experienced aero-embolism on approximately fifteen occasions, beginning as low as 17,000 feet; in two instances the pain was incapacitating.

Three individuals developed scintillating temporal scotomata during descent from 18,000 and 20,000 feet, and in two of these men unilateral temporal blindness persisted for approximately one hour after return to sea level. These individuals gave no family or personal history of migraine, and the scotomata are considered to have been a delayed manifestation of bubble formation.

Pilots who make repeated rapid ascents, even to moderate altitudes, may be expected to experience bends, and perhaps visual defects, even as low as 18,000 feet.

During the past five years numerous studies have been published relating to all phases of aero-embolism or bends, including the influence of temperature, rate of ascent, duration of stay at altitude, and the effect of repeated ascent. (1, 2). Individual susceptibility has been studied from the point of view of age, weight, amount of adipose tissue, previous trauma, and circulatory status (1). Among aviation personnel, bends is recognized as a condition occurring almost exclusively above 30,000 feet, and a survey of the literature reveals only one report of bends developing below 20,000 feet. Allan (3) described the case of a pilot who was incapacitated by bends in the left elbow on each of three plane flights at 10,000 and 12,000 feet, as well as during a low pressure chamber ascent. A second case reported by Allan concerned a WAVE technician who developed pain and swelling in a previously injured ankle during a low pressure chamber flight at 18,000 feet. In both cases soft tissue calcification about the site of injury was apparent by X-ray. No other published reports of low altitude bends have been found, though there are many unconfirmed stories circulated among experienced chamber personnel of bends occurring as low as 10,000 feet.

In the course of Research Project X-720, a month long study of acclimatization to gradually increasing altitude, several cases of bends occurred at such altitudes, and under such circumstances as may frequently be experienced in modern military aircraft. Though the individual cases were not investigated thoroughly, they are considered worthy of report for this reason.

Three hundred and eighty-seven lock ascents were made during a twenty-eight day period while the chamber was at altitudes from 2,000 to 22,500 feet. Twenty technicians and medical officers made all but a few of these 387 lock ascents, and the cases of bends occurred in this group.

The members of the crew stood fourteen four-hour watches each week, distributed throughout the night and day. All were under increasing tension as the chamber altitude increased, and none could be said to be in the best physical condition. None of the crew, however, was apprehensive about the work. Ascent was at the rate of 4,000 feet per minute, and on most trips the attendant remained for less than fifteen minutes at altitude. Oxygen was used routinely on all ascents above 10,000 feet, the nasal type of BLB mask, with constant flow regulator, being worn. No anoxia occurred among the personnel experiencing bends. Chamber temperature ranged from 65 to 80° F.

Operating with a minimum of personnel and under difficult and trying conditions, it was undesirable from the morale standpoint that any importance be attached to the occurrence of bends, or that the matter be widely discussed. Therefore only casual comment was made on each case and the episodes were patently ignored. It is highly improbable that the symptoms were either feigned or imagined, and none of the three medical officers who developed scotomata were aware of the other cases until their own had been reported.

Case 1: (medical officer). Age 33, weight 160, physical condition fair. Had made 300 chamber ascents during previous four years with increasing susceptibility to bends.

First noted mild pain in akles and wrists after 10-15 minutes at altitudes above 16,000 feet, and pain was present on two out of three ascents above 18,000 feet, being increased by exertion of closing lock door. After making 48 ascents in 19 days, this man made two ascents to 18,000 feet in rapid succession. Upon entering the lock for second descent, he noted a scintillating scotoma in the left temporal field which increased rapidly during descent. At sea level he was nauseated and dizzy and developed complete left temporal blindness with severe right-sided headache. The blindness disappeared after an hour but the severe headache persisted for thirty-six hours. During the next ten days this officer made 26 ascents with no other symptoms than mild joint pain.

Case 2: (medical officer). Age 33, weight 165, physical condition fair. Very little previous experience with altitude, no previous bends.

On several occasions developed mild joint pains after an hour at altitudes above 17,000 feet. After thirteen ascents in twenty-one days, developed a right temporal scintillating scotoma upon reaching sea level after approximately two hours at 20,000 feet. There was right temporal blindness, with pallor, anusea, vertigo and occipito-orbital headache. The visual defect persisted for about one hour, and the headache for twelve hours. Ten subsequent ascents, each preceded by twenty to thirty minutes of pre-oxygenation produced no symptoms.

Case 3: (medical officer). Age 35, weight 140, physical condition excellent. Numerous chamber ascents during previous two years with occasional bends at above 30,000 feet.

This man developed slight and transitory joint pains three or four times after twenty minutes at altitudes between 18,000 and 20,000 feet. During descent from 21,000 feet (having made 24 prior ascents) he developed a scintillating right temporal scotoma which persisted for forty-five minutes, causing difficulty in reading instruments, but no true blindness. Slight weakness, dizziness and headache. Ten subsequent ascents gave no symptoms.

Case 4: (corpsman). Age 28, weight 160, physical condition poor. On his sixteenth ascent developed minor joint pains in both feet and ankles, and on his eighteenth ascent, at 18,000 feet, developed severe pain in both knees and ankles, necessitating descent after fifteen minutes at altitude.

Case 5: (corpsman). Age 21, weight 130, physical condition fair. After fourteen ascents in nineteen days, this man developed disabling bends in knees, fingers and hips which became so severe as to require descent after twenty minutes at 19,000 feet. Pain and stiffness persisted in fingers of right hand for three days. Ten subsequent ascents as high as 22,000 feet caused no symptoms.

Case 6: (corpsman). Age 26, weight 180 (adipose), physical condition poor. Having made ten ascents to increasing altitude, without symptoms, he developed disabling pain in right shoulder at 21,000 feet, which persisted for several hours after descent. Four subsequent ascents as high as 22,000 feet caused no symptoms.

DISCUSSION

These six individuals experienced bone and joint pains at altitudes which rarely give rise to clinical aero-embolism, though gas bubbles have been shown to appear in spinal fluid (4) as low as 18,000 feet. Ordinarily the operating crew were required to perform only light work during their sojourn at altitude, though the effort required to seal the lock door upon starting descent was considerable. Although in Case 1 and Case 3 the onset of the pain was definitely hastened by exertion, in the majority of instances exercise did not appear to be a contributing factor.

Susceptibility to bends has been reported to increase with repeated exposure to decompression (2, 5), though these reports have concerned personnel making frequent ascents

above 30,000 feet. It is believed that in the six cases reported here, the daily ascents, together with increasing nervous tension surrounding the project, contributed considerably to the development of bends. The rate of ascent employed here (4,000 feet per minute) can now be attained by many military aircraft; consequently pilots who are called upon to make frequent rapid ascents while under stress may be expected to develop aero-embolism such as experienced here, a fact which should be borne in mind by flight surgeons.

The development of scintillating scotomata has been fully described by Engel and his co-workers (6), who discussed 46 episodes occurring in 16 individuals during ascents of 30,000 to 38,000 feet. They do not consider these scotomata to be manifestations of aero-embolism, since the symptoms as well as the clinically demonstrable visual defects persisted or often grew worse after descent. Instead they were able to uncover either family or personal histories of migraine in 11 of their 16 subjects, and consider the attacks to be manifestations of migraine precipitated by decompression. None of the three medical officers who experienced scotomata in this study gave such a history however. Rodbard (7) describes 7 cases of visual disturbances occurring during descent from 38,000 feet and raises the question of the role of recompression in dislodging bubble emboli. Burkhardt (5) also mentions scotomata, but does not elaborate on the finding. Motley (1) in a study of bends experienced by 68,422 individuals mentions the incidence of visual symptoms to be 0.15%, but does not describe these. Obviously, however, if the syndrome may develop as low as 18,000 feet in personnel making repeated ascents, it may have considerable importance to pilots.

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